XR-3 TURNING PERFORMANCE

James Harold Roberts

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

XR-3 TURNING PERFORMANCE

by

James Harold Roberts

December 1974

Thesis Advisor: D. M. Layton

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This paper documents the turning performance testing which was conducted on the XR-3 captured air bubble surface effect ship testcraft between May and October, 1974. This testing was accomplished in order to obtain data requested by the Naval Ship Research and Development Center, and to provide additional data for on-going XR-3 programs at the Naval Postgraduate School.

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XR-3 Turning Performance

by

James Harold Roberts
Commander, United States Navy
B.S., Naval Postgraduate School, 1966

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

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December 1974

ABSTRACT

This paper documents the turning performance testing which was conducted on the XR-3 captured air bubble surface effect ship testcraft between May and October, 1974. This testing was accomplished in order to obtain data requested by the Naval Ship Research and Development Center, and to provide additional data for on-going XR-3 programs at the Naval Postgraduate School.

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I. INTRODUCTION

A. BACKGROUND

In addition to the considerable amount of testing that has been accomplished on the XR-3 testcraft, both at the Naval Postgraduate School and elsewhere, at least three series of water-tank model testing have been done by the Aerojet General Corporation, Lockheed Missile & Space Company, and the Naval Ship Research and Development Center (NSRDC).

The scope of this testing of various scale XR-3 models under closely controlled conditions has resulted in the collection of data that is useful in developing mathematical models for simulation of larger captured air bubble craft. The advantage of having a full-scale XR-3 doing real life testing is that not only can the data that are obtained be used for additional validation of the math models, but it can also provice some degree of proof of scaling factors when compared with the water-tank model data. Appendix A contains XR-3 dimensions and other measurements.

The Simulation Group of NSRDC requested certain turning performance tests, in references 1, 2 and 3, which were designed to attune as closely as possible with model testing data previously gathered. Test plans were prepared (see references 4 and 5) and tests conducted on the XR-3 at its test site at Lake San Antonio, California, and the raw tape

recorded data were furnished to NSRDC for evaluation. These data, as well as additional data points, were examined and evaluated for this report.

B. OBJECTIVES

In addition to furnishing the Simulation Group, NSRDC, with these data, portions of the data were furnished to the Naval Postgraduate School captured air bubble simulation group for the continued development and validation of their XR-3 math model. There were, therefore, three primary objectives in this project:

(1) Full scale simulation of model turning performance for math model validation and scaling factor validation for the Naval Ship Research and Development Center.

(2) Generation of data for the continued development and validation of the NPS XR-3 math model.

(3) Obtaining turning response characteristics of the XR-3 testcraft.

Because of the specialized characteristics of the XR-3 testcraft (outboard engine propulsion, steering by turning the propulsion engines, lack of fine control over seal and plenum pressurization, and so forth), it might appear that detailed knowledge of the turning performance characteristics is of limited use. Such, however, is not the case. Consider, for example, one of the derived relationships - that of yaw rate as a function of rudder deflection. The importance of the fact that X degrees of rudder deflection produces Y degrees per second

of yaw rate for this particular testcraft may be insignificant. But the significance of being able to determine the amount of sideslip in a Captured Air Bubble craft of similar sidewall/seal design at Y degrees of yaw rate becomes of experimental value when it is known that X degrees of XR-3 testcraft rudder deflection will produce this amount of yaw rate.

Therefore, the meeting of objectives (1) and (2), as listed above, are of current interest and the meeting of objective (3) is of long term interest.

II. INSTRUMENTATION

During the period of time (June 1972 to February 1973) that the XR-3 was being fitted with a new type of membrane seal, the onboard data acquisition system was expanded and improved in order that extensive performance testing of the modified testcraft could take place (References 6 and 7).

A. RECORDING UNIT

A Pemco Model 120-B magnetic tape recorder is used as a recording unit for the data acquisition system. The tape recorder is capable of recording $\pm$ 1 volts RMS $\pm$ .5% on each of 14 data tracks. The inputs to the Pemco recorder are received from a signal amplifier and transducer package which is described in reference 6.

B. PARAMETERS ANALYZED

The parameters of interest which were inputs to the recorder were: port and starboard thrust; pitch and roll angles; pitch, roll and yaw rates; velocity; rudder angle; surge, sway and heave acceleration; and bow and stern seal pressure.

The signal from each of the port and starboard thrust transducers was amplified so that a recorded range of zero to 1000mv was equivalent to zero to 500 pounds thrust.

The pressure in each of the seals was detected by pressure transducers and amplified so that a recorded range of zero to 1000 mv was equivalent to zero to 60 psf.

The velocity transducer/amplifier circuitry was set up so that zero to 1000 mv input to the recorder was equivalent to zero to 40 knots.

Rudder angle was similarly sensed and transduced to the recorder so that zero to 900 mv corresponded to -45 to +45 degrees or rudder input.

Finally, the gyro package installed in the XR-3 measured pitch, roll and yaw angles and pitch, roll and yaw rates. The output of the gyro modes (input to the recorder) was adjusted so that zero to 1000 mv corresponded to -15 to +15 degees of pitch and roll angle, -180 to +180 degrees of yaw angle and -30 to +30 degrees per second in pitch, roll and yaw rates. For the accelerometers, zero to 1000 mv was equivalent to -1.0 to +1.0 "g"' variation.

Appendix B lists the parameters of interest together with respective calibration ranges. To calibrate the entire data acquisition system, step inputs of 0, 500, and 1000 mv were recorded on each channel of the tape recorder prior to the initiation of each test sequence. Appendix B also lists transducer locations aboard the testcraft.

III. TURNING PERFORMANCE TESTING

The test series described herein was conducted from 29 May through 4 October 1974. All tests were accomplished at Lake San Antonio in Monterey County, California. The testcraft was in a fixed configuration with the data acquisition and communication system installed, one crewmember and a full fuel load. During testing, weight (neglecting negligible fuel consumption), center of gravity, and seal positions were maintained constant. Further, all testing was done in smooth water with negligible wind effects and within the specified test conditions set forth in the general test plan (Reference 5).

A. PURPOSE

The purpose of turn performance testing of the XR-3 was to collect and analyze test data as practical and appropriate in order to draw conclusions and make recommendations regarding over-all XR-3 turning performance. Two types of turns were studied: (1) rudder induced turns and (2) turns due to thrust differential.

B. RUDDER INDUCED TURNS

As can be seen from figures 1 and 2, actuation of the rudder on the XR-3 is simply the variation of the thrust vector from two interconnected outboard engines. Detailed discussion of the XR-3 rudder system is not necessary, however, since this paper is concerned with only the

relationship between an arbitrary index of rudder angle and corresponding turning performance parameters. With this relationship thus established, it is possible to simulate desired performance parameters of other testcraft or to compare that performance with the XR-3.

On each test run the pilot would establish the testcraft on a suitable heading and stabilize forward speed at 20 knots. With the testcraft thus stabilized, the pilot would smoothly and rapidly deflect the rudder at 2 degrees per second and maintain the selected rudder deflection angle for 60 seconds, which enabled the testcraft to become stabilized in a turn with a new constant velocity. The rudder would then be smoothly returned to zero deflection angle and the testcraft again allowed to stabilize at constant forward velocity. This procedure was repeated at least twice for each of the rudder deflection angles selected (-15, -12, -9, -5, 0, +5, +9, +12, and +15 degrees). A total of thirty one (31) runs were made in this portion of the testing.

C. TURNS INDUCED BY THRUST DIFFERENTIAL

In these tests the pilot would establish the testcraft on a suitable heading with constant velocity (20 knots) as before. The pilot would then reduce the port or starboard throttle to an arbitrary low power setting (step power reduction) while maintaining a zero rudder angle. The moment in haw thus created by the differential thrust induced a turn. The pilot would permit the testcraft to stabilize in the turn and

then applied sufficient opposite rudder to establish a zero turn (yaw) rate.

D. GENERAL

Throughout the test runs for both rudder induced turns and turns induced by moment generation (thrust differential), the parameters desired (Appendix A) were recorded on tape in terms of unfiltered voltage outputs, as previously described, and were synchronized with voice recordings which assisted in interpretation of the input signals. Voice data on the tape consisted of center of gravity location, testcraft weight, rudder and thrust application marks, and test date. Voice notation was also made whenever unexpected inputs to the recorder were encountered, such as aborted runs and crossing the wake of another craft.

After completion of each day's testing, the Pemco tape recorder was removed from the XR-3 and installed in the NPS Mobile Data Facility for data processing and reduction.

E. DISPLAY AND INTERPRETATION OF DATA

In order to initially interpret the large amount of data which was stored on the 14 track tape recorder, a Hewlett Packard 2-channel strip chart recorder was used (Figure 3). With this instrument any two channels from the tape recorder can be simultaneously plotted against time to provide the user with a graphical representation of the

data. In addition an edge track, with event marker, can be used to mark tape count position. After appropriate scaling of the strip chart was accomplished, measurements of the chosen parameters could be made directly.

For all test runs, testcraft weight was constant at 5810 pounds, the center of gravity was located 119 inches forward of the stern transom and the front seal was pressurized to 23.0 pounds per square foot. Rear seal pressure was held at 24.5 psf and both seals were set with the trailing edge level with the bottom of the hull.

The coordinate system used herein is a right handed system with the positive (X) axis measured forward. The lateral (Y) axis is measured positive to starboard for yaw rate and acceleration. The vertical (Z) axis is measured positive downward Positive angles are: yaw - bow to starboard, roll - starboard down, and pitch - bow up. Zero pitch and roll are referenced to the X-Y plane parallel to the water surface. Positive rudder deflection is to starboard (generates starboard turn).

FIGURE 1. XR-3, TESTCRAFT - GENERAL APPEARANCE

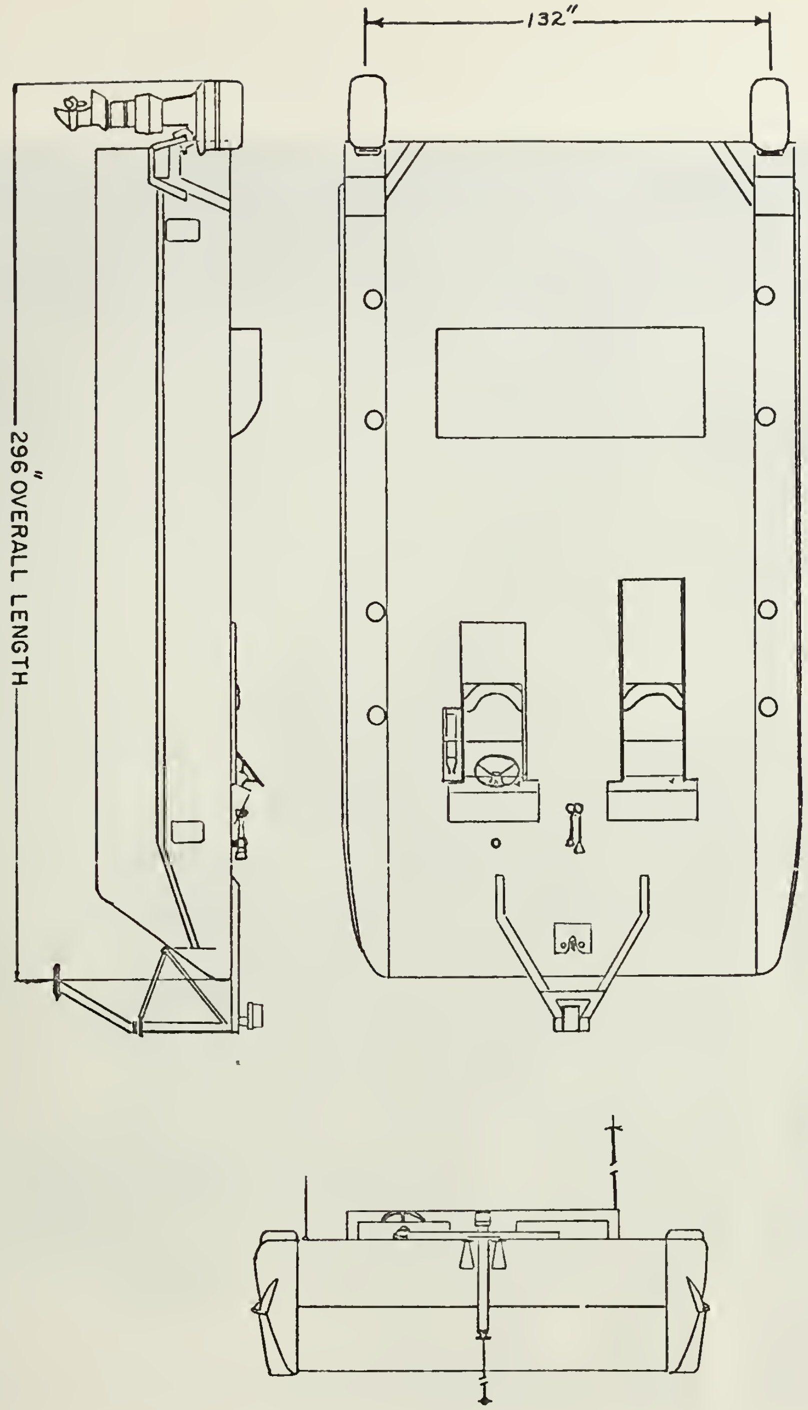

FIGURE 2. GENERAL CONFIGURATION OF XR-3

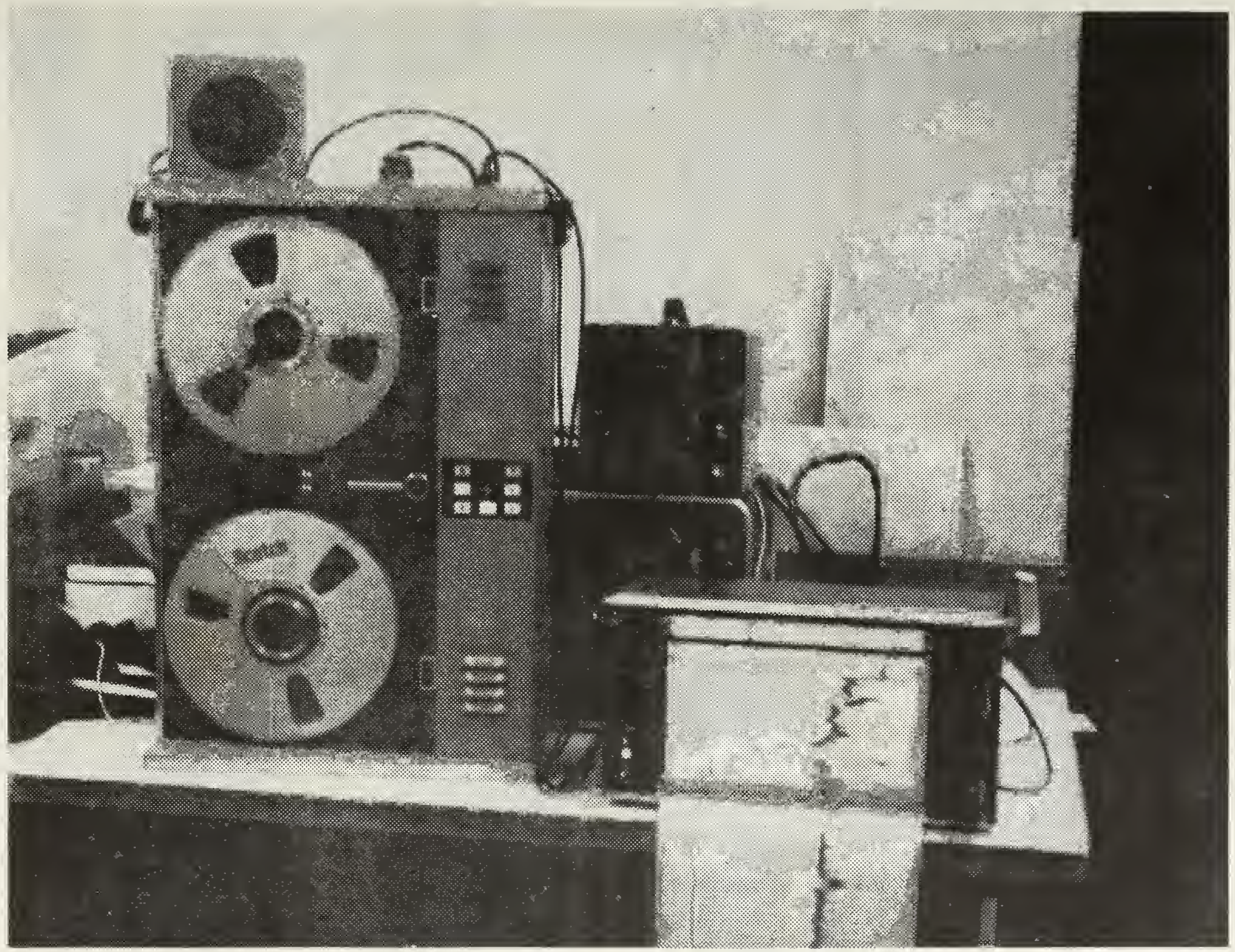

FIGURE 3. DATA REDUCTION SET-UP

IV. RESULTS

A. RUDDER INDUCED TURNS

Velocity, change in thrust, roll angle, pitch angle, yaw rate, lateral acceleration and bow seal pressure are plotted versus rudder deflection angle in figures 5 through 11. Also, steady state velocity and roll angle are plotted versus yaw rate in figures 12 and 13. Likewise, roll angle and yaw rate are plotted versus lateral acceleration in figures 14 and 15. Finally, velocity, roll angle and pitch angle are plotted versus bow seal pressure in figures 16 through 18.

1. Velocity Versus Rudder Deflection

The velocity versus rudder angle curve, figure 5, shows that there is only a slight velocity decrease, approximately one percent, during the first five degrees of rudder deflection. Thereafter, for each additional degree of deflection there is a corresponding decrease in steady state velocity attainable of approximately 0.8 percent. These relationships hold, of course, only within the normal range of rudder deflection angles, i.e., for angles less than 16 degrees. Analysis of the plots of velocity versus rudder angle indicates that for rudder deflection angles between 5 and 15 degrees (port and starboard) it took very nearly one second per degree of rudder deflection for the testcraft to accelerate to a new steady state velocity after rudder was returned to zero deflection.

2. Change in Total Thrust Versus Rudder Deflection

Figure 6 shows that thrust is increased as the magnitude of rudder angle is increased. Roughly, for rudder angles greater than five degrees, there is an increase of approximately 2.7 pounds thrust for each additional degree of rudder deflection within the essentially linear range of the curve.

3. Roll Angle Versus Rudder Deflection

Steady state roll angle generated by rudder deflection is shown in figure 7. As expected, the curve is flat near zero rudder deflection and changes more rapidly as approximately 7 degrees of rudder deflection is exceeded. In all instances, however, roll angle in turns was slight. The roll angle corresponding to the maximum rudder deflection utilized (15 degrees) was only 1.35 degrees. Also as expected positive rudder angles (turns to starboard) produced negative roll angles (roll to port), and vice versa.

4. Pitch Angle Versus Rudder Deflection

Figure 8 shows that for both right and left deflections of the rudder, i.e., in port and starboard turns, the testcraft was found to pitch bow up. For the center of gravity location which existed during testing (119 inches forward of the stern transom), the testcraft assumed a 1.75 degree bow up pitch attitude with zero rudder at cruise velocity (20 knots). From this slightly bow up attitude, deflection of the rudder (turns to port and starboard) generated increasing pitch angles with

increasing rudder deflections. Maximum pitch angle observed was approximately 5.5 degrees at $\pm$ 15 degrees rudder. Non-symmetry of the curve in figure 8 is attributed to unequal distribution of testcraft weight laterally.

5. Yaw Rate Versus Rudder Deflection

Yaw rate increases with increasing rudder angle as shown in figure 9. Positive rudder generates positive yaw rate and vice versa. The slope of the curve shows good yaw rate generation even for small rudder inputs; in other words the curve has a good slope throughout. Figure 9A is a segment of the strip chart plot at 2 inches per second. Analysis of the plot shows that the time lag between actuation of the rudder and resultant steady state yaw rate was small. It was observed that for the slower rudder actuation times (5-7 seconds) there was virtually no time lag in yaw rate generation. Even for rapid (2-3 second) rudder actuation to large deflection angles (12-15 degrees), there was only a 5-7 second time lag for establishment of steady state yaw rate. There was a maximum two (2) second lag between rudder actuation and yaw rate cessation as the rudder was returned to zero.

6. Lateral Acceleration Versus Rudder Deflection

The curve in figure 10 shows that lateral acceleration is not a linear function of rudder deflection. Positive rudder angles generate negative lateral acceleration as would be expected, and vice versa. The curve is flat between minus 6 and plus 6 degrees rudder angle which

indicates that very little lateral acceleration is generated within this range of rudder deflection angles. The magnitude of lateral acceleration experienced at all rudder angles tested was small, i. e., under .05 "g" for rudder angles less than ± 15 degrees. Lateral accelerations would have been somewhat higher had velocity not been allowed to drop in the turns.

7. Bow Seal Pressure Versus Rudder Deflection

Bow seal pressure is generally symmetric about the vertical axis in figure 11 for both right and left rudder angles, however, slightly higher pressures are generated during starboard turns. This probably due to the unsymmetrical lateral loading of the testcraft (heavier to starboard). This condition of higher bow seal pressures in starboard turns can also be due to the higher pitch angles (bow up) associated with starboard (vice port) turns as shown in figures 8 and 18. Within the essentially linear range of the curve, i. e., 5 to 15 degrees of rudder angle inclusive, the bow seal pressure increases approximately 0. 17 psf per degree of rudder deflection. This for both port and starboard turns.

8. Velocity Versus Yaw Rate

Figure 12 is a crossplot of figures 5 and 9 to show the decrease in velocity associated with increased yaw rate for both port and starboard turns. It should be noted that there is little change in velocity until ± 1. 5 deg/sec of yaw rate is exceeded.

9. Roll Angle Versus Yaw Rate

The inverse relationship of roll angle and yaw rate is shown in figure 13. Increasing right (positive) yaw rate generates increasing left (negative) roll and vice versa. Again, for small rates of yaw, i.e., between $\pm$ 2.0 deg/sec, roll angle is virtually unaffected. For larger magnitudes of yaw rate, roll angle response is greater but remains relatively small even at the maximum yaw rate observed. The maximum roll angle observed was only 2.3 degrees at minus 4 deg/sec yaw rate. Figure 13 shows that smaller roll angles were generated in response to positive yaw rates. This apparent non-symmetry of the inverse relationship is due to the unequal lateral loading which existed on the testcraft as mentioned earlier.

10. Roll Angle Versus Lateral Acceleration

A crossplot of figures 7 and 10 reveals the nonlinear relationship between lateral acceleration and roll angle as shown in figure 14. Here the relationship between rudder angle, lateral acceleration and roll angle can be observed. It must be kept in mind that this relationship exists only for an initial cruise velocity of 20 knots at zero rudder angle and where velocity is permitted to drop to a new steady state value in the turns at constant power. As expected, positive lateral acceleration produces positive roll angles; both of which are associated with negative rudder angles. Conversely negative lateral acceleration and roll angles are associated with positive rudder angles. The magnitudes

of both roll angles and lateral accelerations are small in response to rudder deflections tested as stated earlier.

11. Lateral Acceleration Versus Yaw Rate

Figure 15 is a crossplot of figures 9 and 10 and shows the inverse linear relationship which exists between lateral acceleration and yaw rate. The negative slope indicates that there is a negative lateral acceleration response to positive yaw rate such that for every one degree per second of positive yaw rate input, there is a corresponding negative lateral acceleration of .0088 "g".

12. Bow Seal Pressure Versus Velocity

Figure 16 is a crossplot of figures 5 and 11 and shows the near relationship of bow seal pressure as a function of steady state velocity in turns generated by various rudder deflections. Maximum bow seal pressure is seen to exist at the lower velocities which correspond to higher rudder deflection angles.

13. Bow Seal Pressure Versus Roll Angle

A crossplot of figures 7 and 11 is presented in figure 17 which shows bow seal pressure as a function of roll angle at various rudder deflection points. Bow seal pressure is seen to increase slightly (up to 2 psf) with increasing roll angles in either direction. Interestingly, seal pressure appears more sensitive to roll angles within $\pm$ .35 degrees of roll. Outside this range the slope of the curve is flatter, indicating

diminished seal pressure increase with larger roll angles (appx. 1.75 psf increase per degree of roll).

14. Bow Seal Pressure Versus Pitch Angle

The relationship between bow seal pressure and testcraft pitch angle in turns was obtained from the crossplot of figures 8 and 11 which is presented in figure 18. Bow seal pressure variation is very nearly a linear function of pitch angle under the conditions tested except for small perturbations in pitch. Here again, consideration must be given to the fact that velocity was not held constant during the testing.

B. TURNS INDUCED BY THRUST DIFFERENTIAL

For varying yaw moments due to thrust differential, rudder deflection angle to maintain zero yaw rate was determined (Figure 19). The negative (same magnitude, opposite sign) of rudder angles to prevent yaw rate at a given value of yaw moment are of course the values of rudder angle to create the same yawing moment in the opposite direction with zero thrust differential.

The signs of the rudder angles to prevent yaw rate due to thrust differential were therefore reversed and plotted versus yaw moment (Figure 19A). The positive linear slope of the resulting curve indicates that the yaw moment versus rudder deflection angle is unstable. This means that increasing positive rudder deflection generate increasing positive yawing moments and vice versa. Figure 19A also shows a +67.5 ft. lb. rate of yaw moment increase per degree of positive rudder deflection.

C. PARAMETERS NOT ANALYZED

Throughout the test sequence, all perturbations in pitch rate, fore and aft (surge) acceleration and vertical (heave) acceleration were less than their respective experimental error. Consequently, no analysis of these four parameters was attempted.

V. CONCLUSIONS

The following conclusions may be drawn from the data presented.

For a given decrease in velocity due to rudder deflection, there should be a corresponding increase in thrust if power remains constant (this from P=TV). Figures 5 and 6 confirm this relationship since the curve of velocity versus rudder angle is essentially the inverse of the curve of thrust versus rudder angle. Additional data points would have no doubt made the curves more accurate; however, the general relationship of thrust to velocity is clearly apparent.

For all rudder deflection angles used, the testcraft is very stable in roll. Maximum roll angle at $\pm$ 15 degrees or rudder ($\pm$ 5 degs per sec of yaw rate) was only $\mp$ 1.35 degrees.

With increasing rudder deflection angles, both port and starboard, there is an increasing bow up pitch generated. Pitch angles attained were relatively small however, i.e., less than 5 degrees.

At cruise velocity, the magnitude of yaw rates generated by rudder deflections and the associated yaw rate response times were quite acceptable. In other words the testcraft responded rapidly and generated good rates of turn with deflections of rudder (Figures 9 and 9A).

Since velocity was not held constant during the turns tested, this unwanted variable was introduced into many of the curves plotted. For

instance, a more exact relationship between bow seal pressure and pitch angle would have been possible had velocity been maintained constant during the turns.

The yaw moment versus rudder angle curve (Figure 19A) is a straight line with positive slope, indicating the unstable linear relationship which exists between these two parameters.

No side venting of plenum air was observed during the turning performance testing.

V = Velocity

ΔT = Change in Thrust

ϕ = Roll Angle

θ = Pitch Angle

$\dot{\psi}$ = Yaw Rate

P_B = Bow Seal Pressure

δr = Rudder Deflection

V	FIG. 5				
ΔT	FIG. 6				
ϕ	FIG. 7				
θ	FIG. 8	FIG.	FIG.		
$\dot{\psi}$	FIG. 9	FIG. 12	FIG. 13		
LAT'L ACCEL.	FIG. 10		FIG. 14		FIG. 15
P_B	FIG. 11	FIG. 16	FIG. 17	FIG. 18	
YAW MOMENT	FIG. 19				
	δr	VEL.	ϕ	θ	$\dot{\psi}$

FIGURE 4. MATRIX OF PLOTS

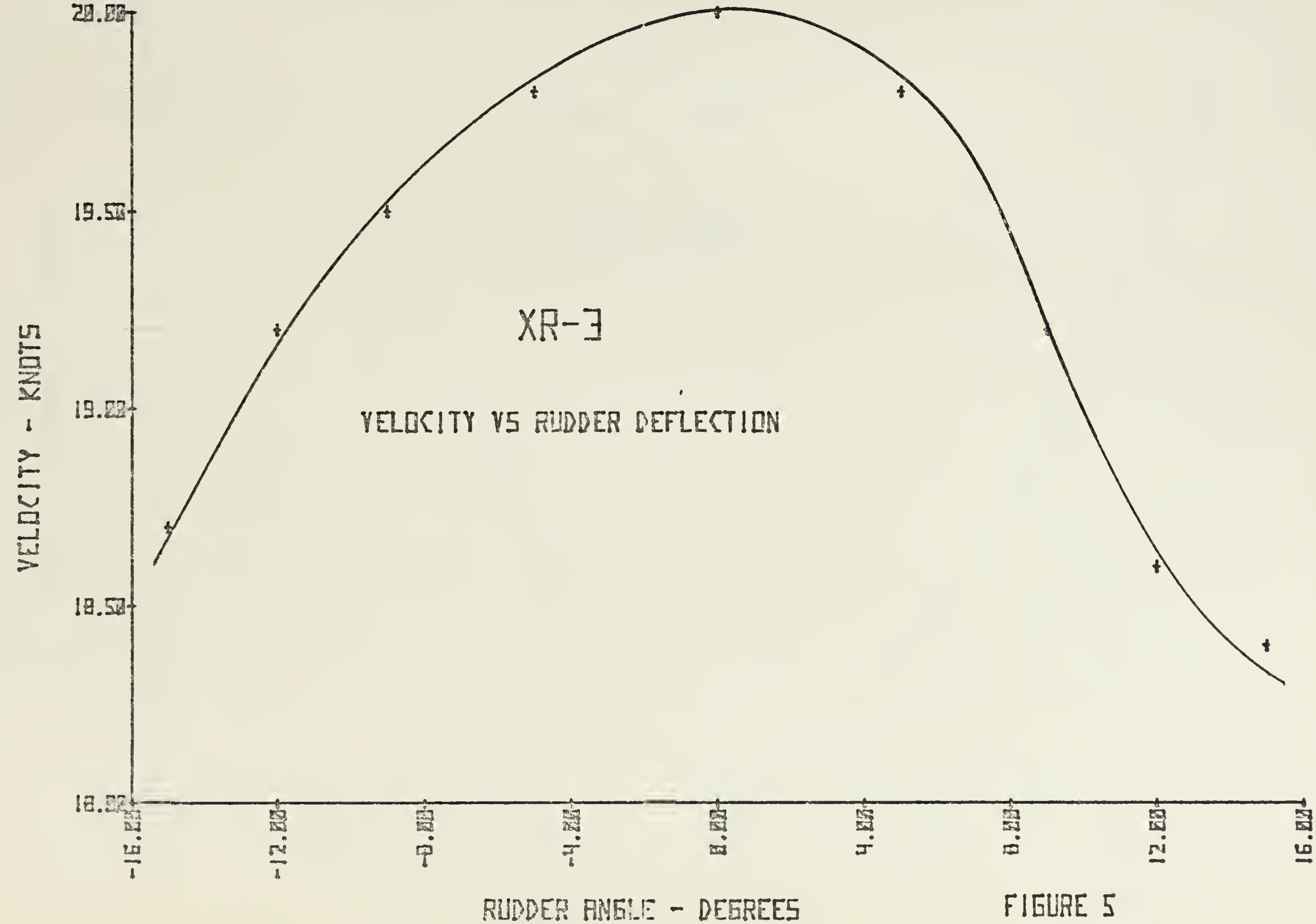
XR-3
VELOCITY VS RUDDER DEFLECTION
VELOCITY - KNOTS
20.00
19.50
19.00
18.50
18.00
-16.00
-12.00
-8.00
-4.00
0.00
4.00
8.00
12.00
16.00
RUDDER ANGLE - DEGREES

FIGURE 5

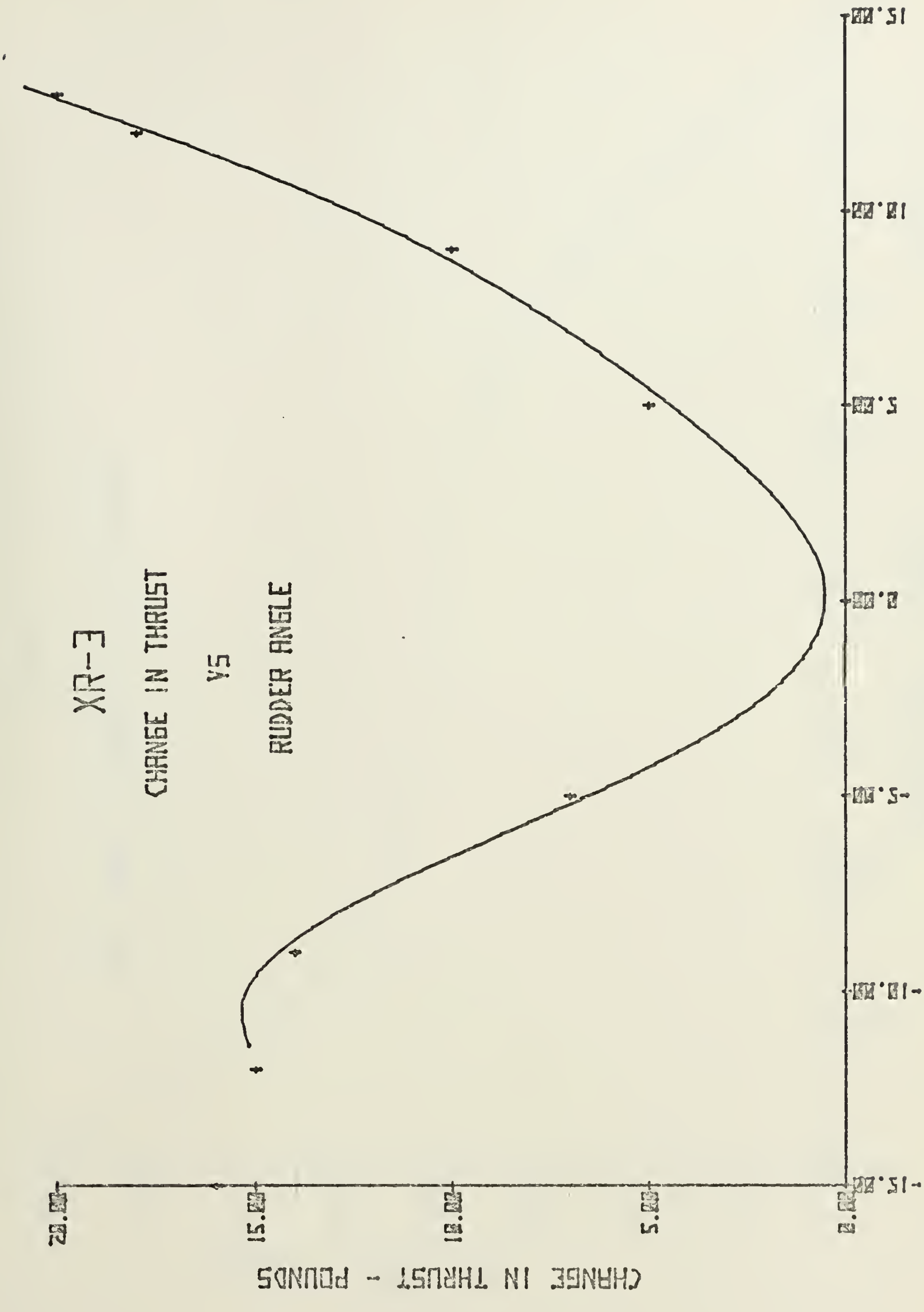
XR-3
CHANGE IN THRUST
VS
RUDDER ANGLE
CHANGE IN THRUST - POUNDS
RUDDER ANGLE - DEGREES
20.00
15.00
10.00
5.00
0.00
-15.00
-10.00
-5.00
0.00
5.00
10.00
15.00

FIGURE 6

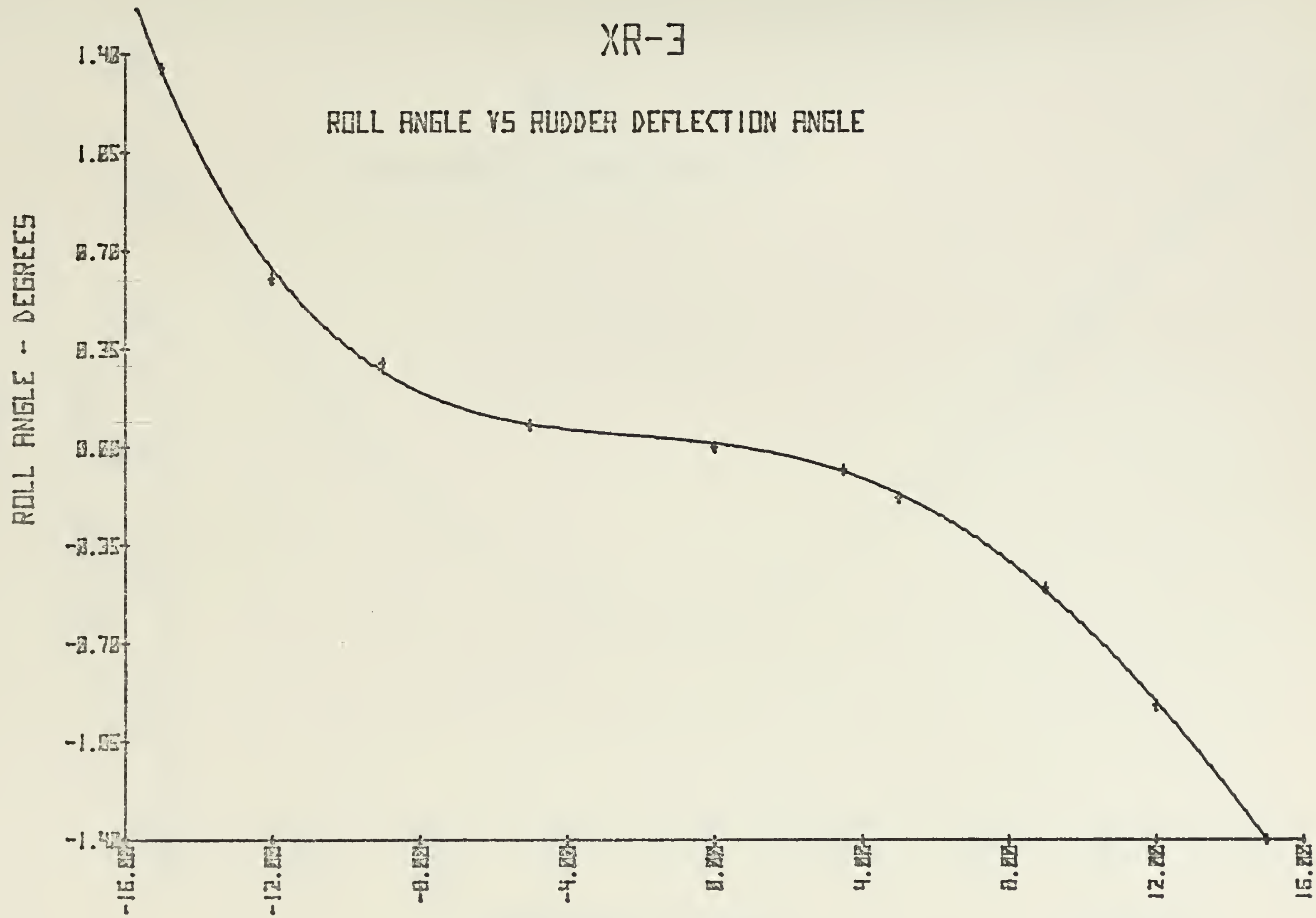
XR-3
ROLL ANGLE VS RUDDER DEFLECTION ANGLE
ROLL ANGLE - DEGREES
1.40
1.05
0.70
0.35
0.00
-0.35
-0.70
-1.05
-1.40
-16.00
-12.00
-8.00
-4.00
0.00
4.00
8.00
12.00
16.00
RUDDER ANGLE - DEGREES

FIGURE 7


XR-3
PITCH ANGLE VS RUDDER DEFLECTION
PITCH ANGLE - (DEG)
RUDDER ANGLE - (DEG)
FIGURE 8

FIGURE 8

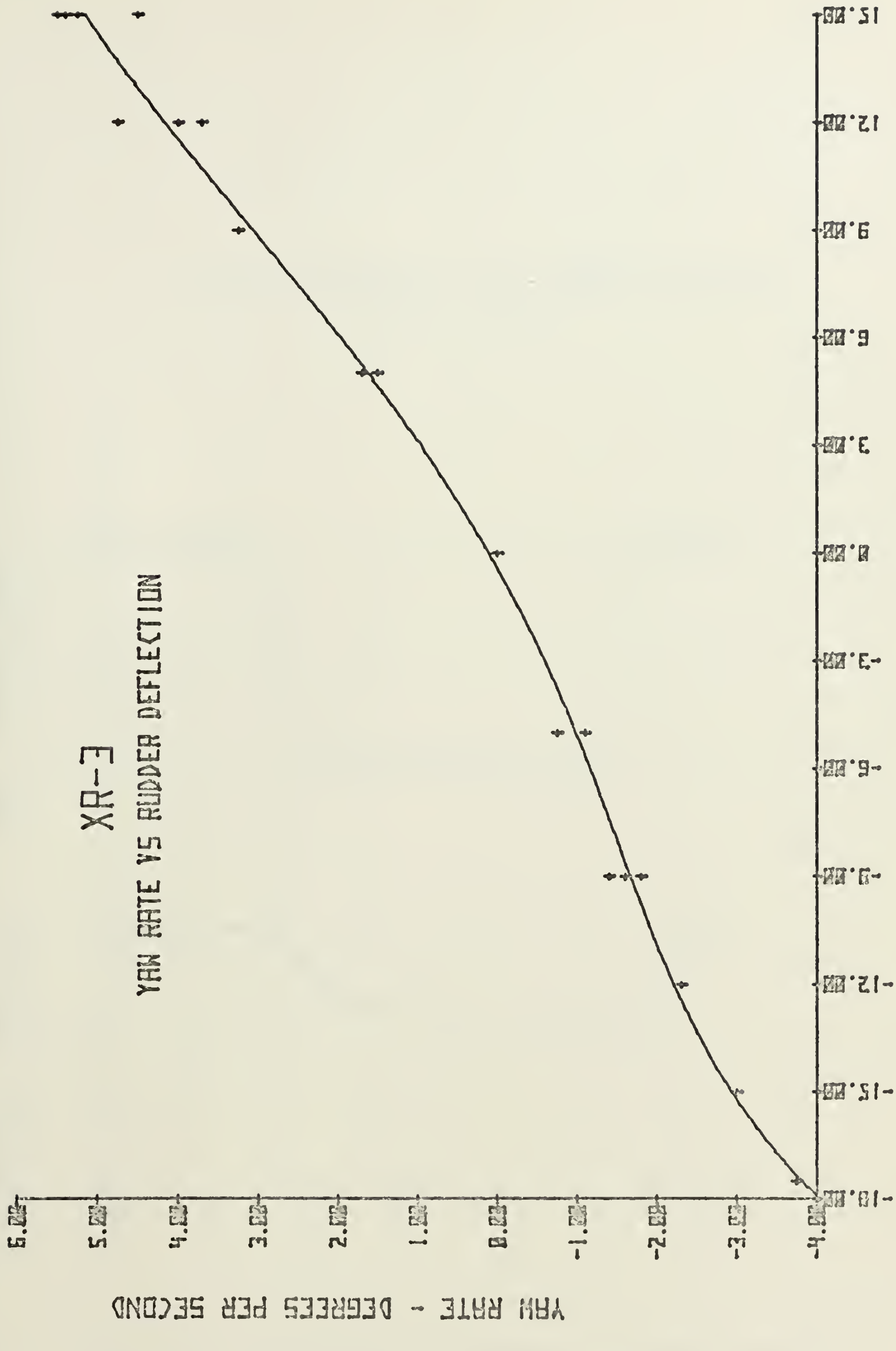
XR-3
YAW RATE VS RUDDER DEFLECTION
YAW RATE - DEGREES PER SECOND
RUDDER ANGLE - DEGREES
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
-18.00
-15.00
-12.00
-9.00
-6.00
-3.00
0.00
3.00
6.00
9.00
12.00
15.00

FIGURE 9

NOTE: PEN MOVEMENT IS TWO INCHES PER MINUTE

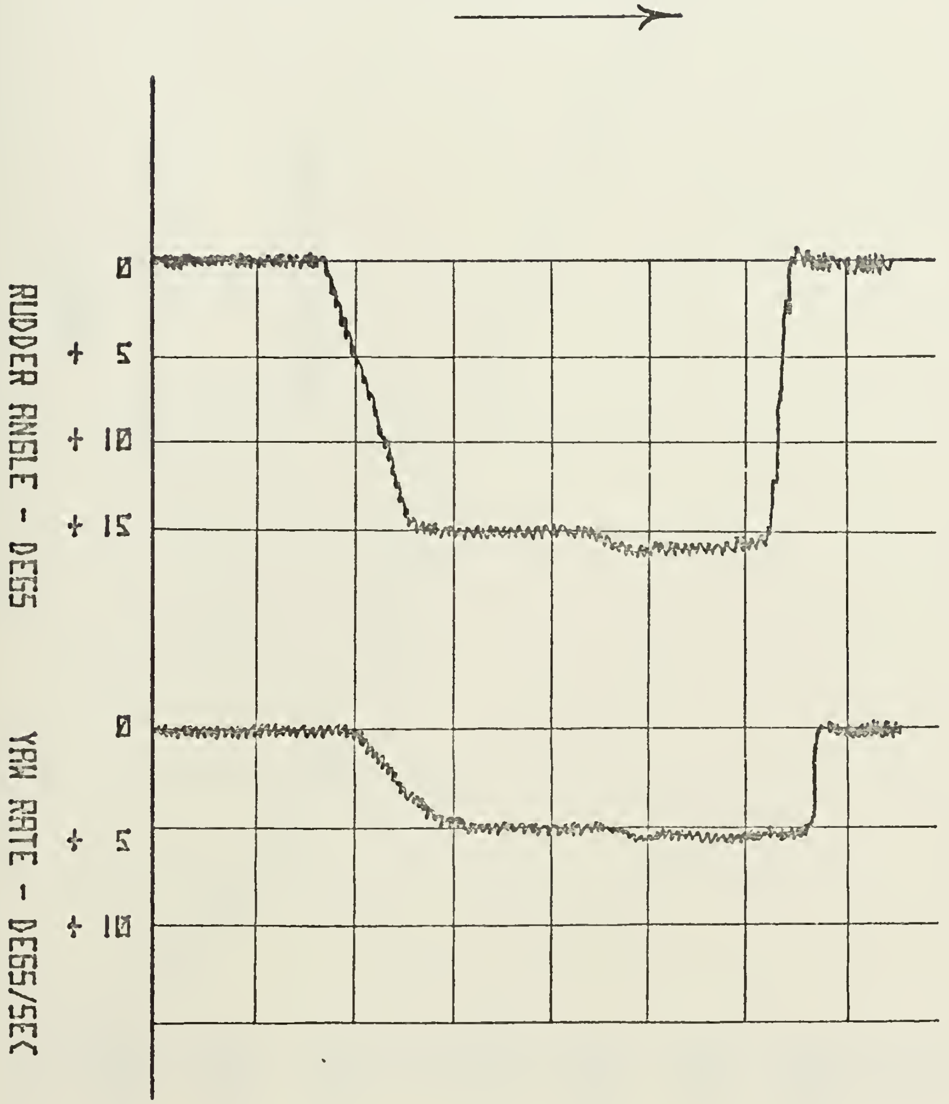

FIGURE 9A - SAMPLE YAW RATE RESPONSE TO RUDDER DEFLECTION

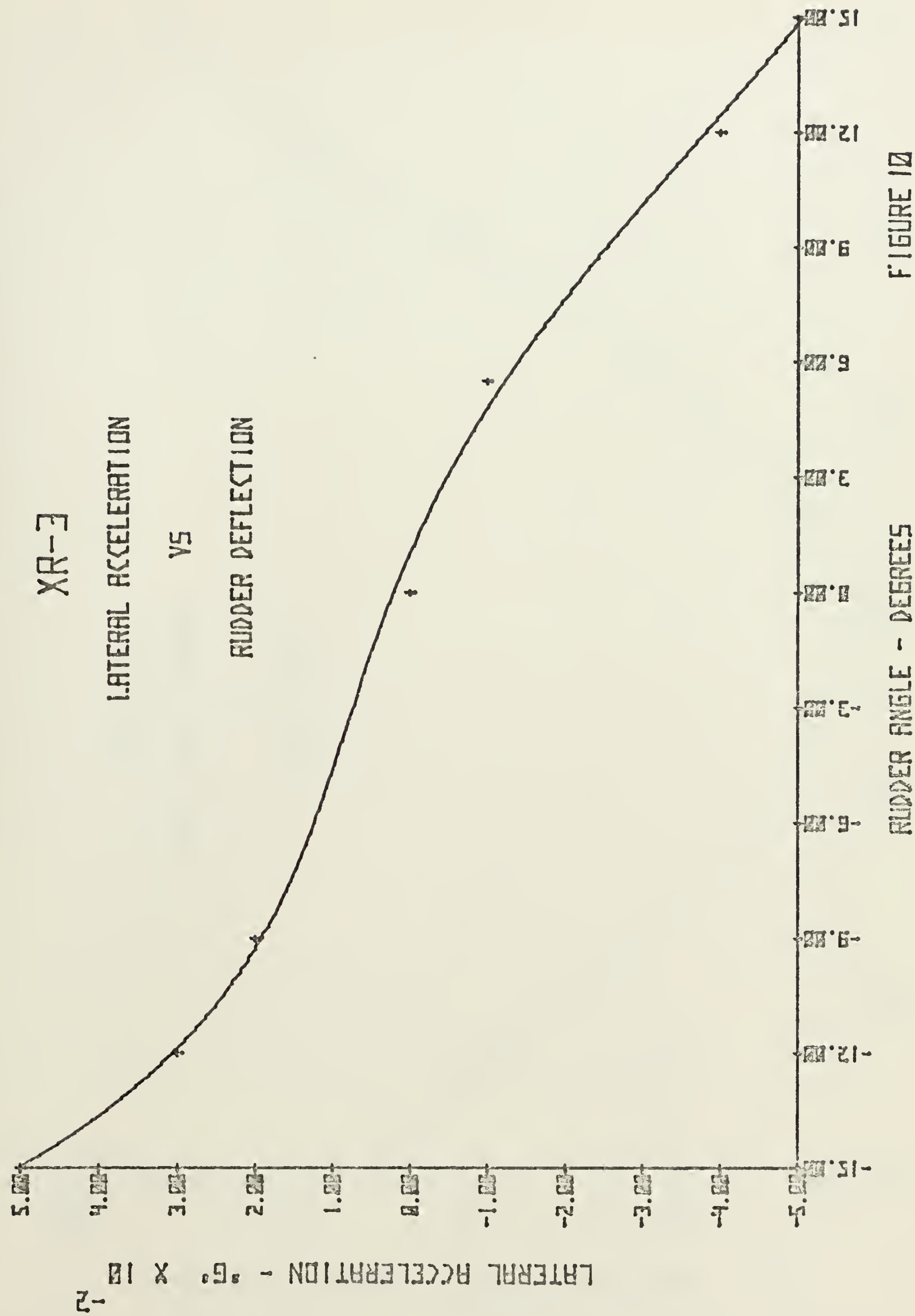
XR-3
LATERAL ACCELERATION
VS
RUDDER DEFLECTION
LATERAL ACCELERATION - "G" X 10^-2
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-15.00
-12.00
-9.00
-6.00
-3.00
0.00
3.00
6.00
9.00
12.00
15.00
RUDDER ANGLE - DEGREES

FIGURE 10

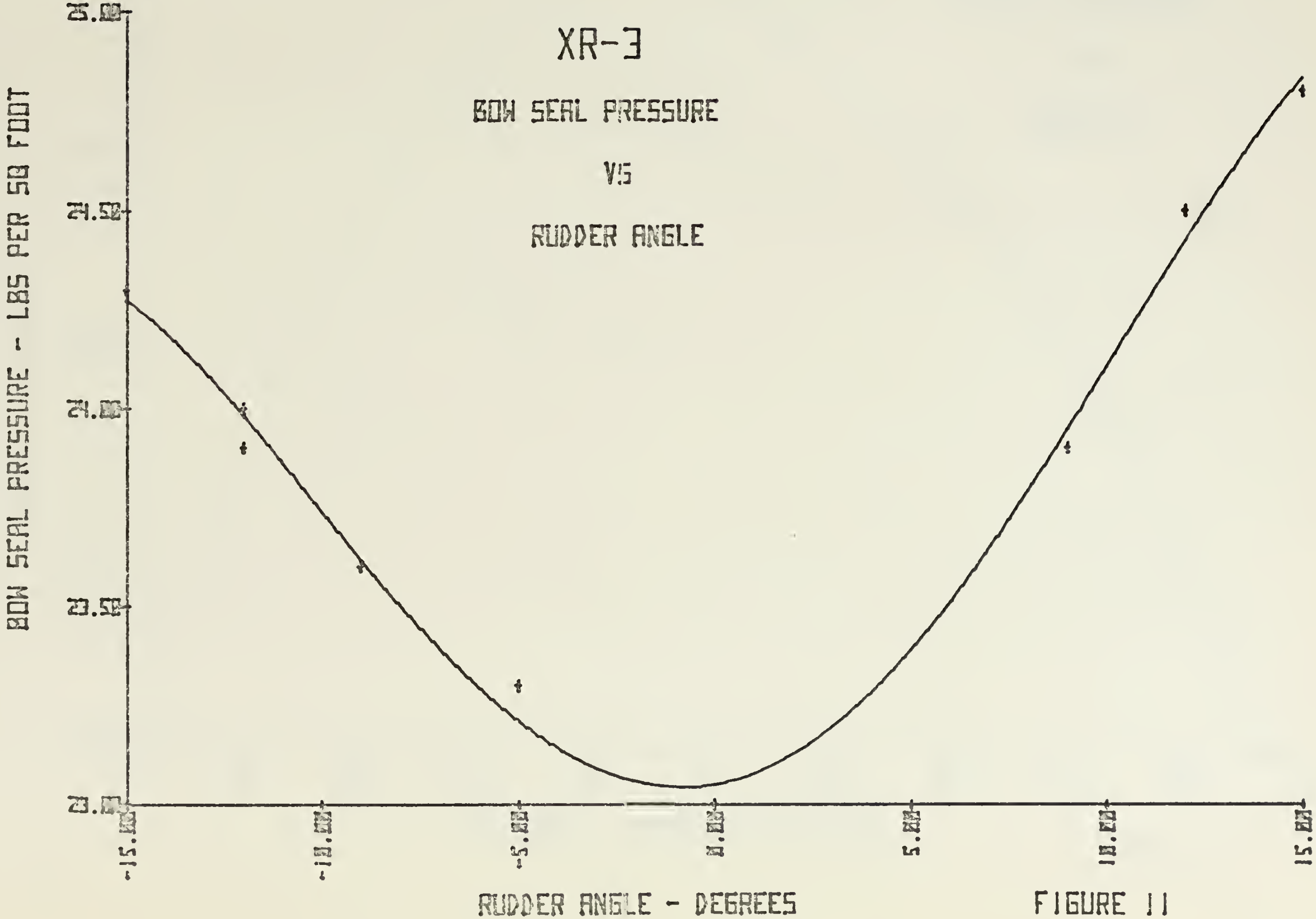
XR-3
BOW SEAL PRESSURE
VS
RUDDER ANGLE
BOW SEAL PRESSURE - LBS PER SQ FOOT
25.00
24.50
24.00
23.50
23.00
-15.00
-10.00
-5.00
0.00
5.00
10.00
15.00
RUDDER ANGLE - DEGREES

FIGURE 11

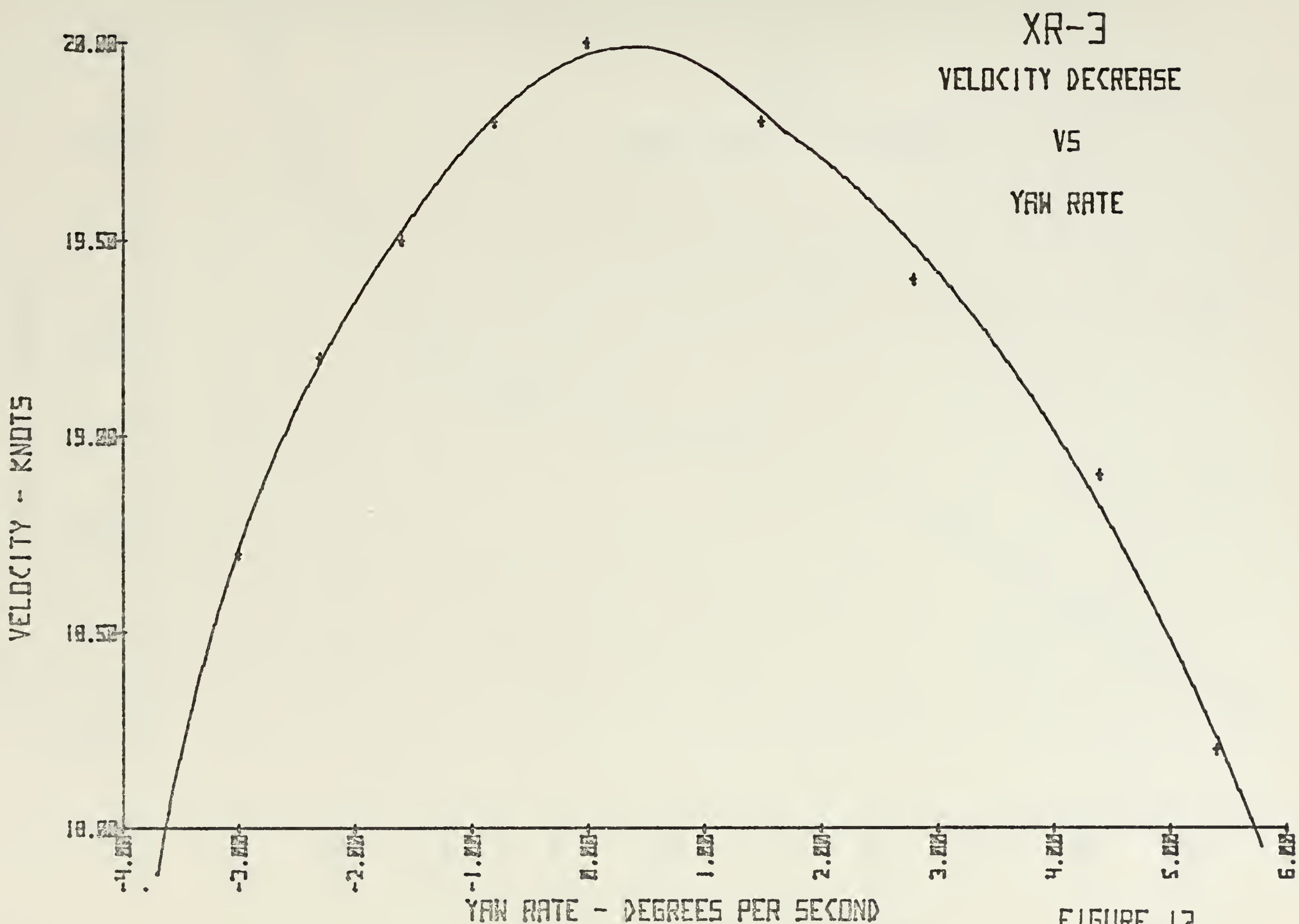
XR-3
VELOCITY DECREASE
VS
YAW RATE
VELOCITY - KNOTS
20.00
19.50
19.00
18.50
18.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
YAW RATE - DEGREES PER SECOND

FIGURE 12

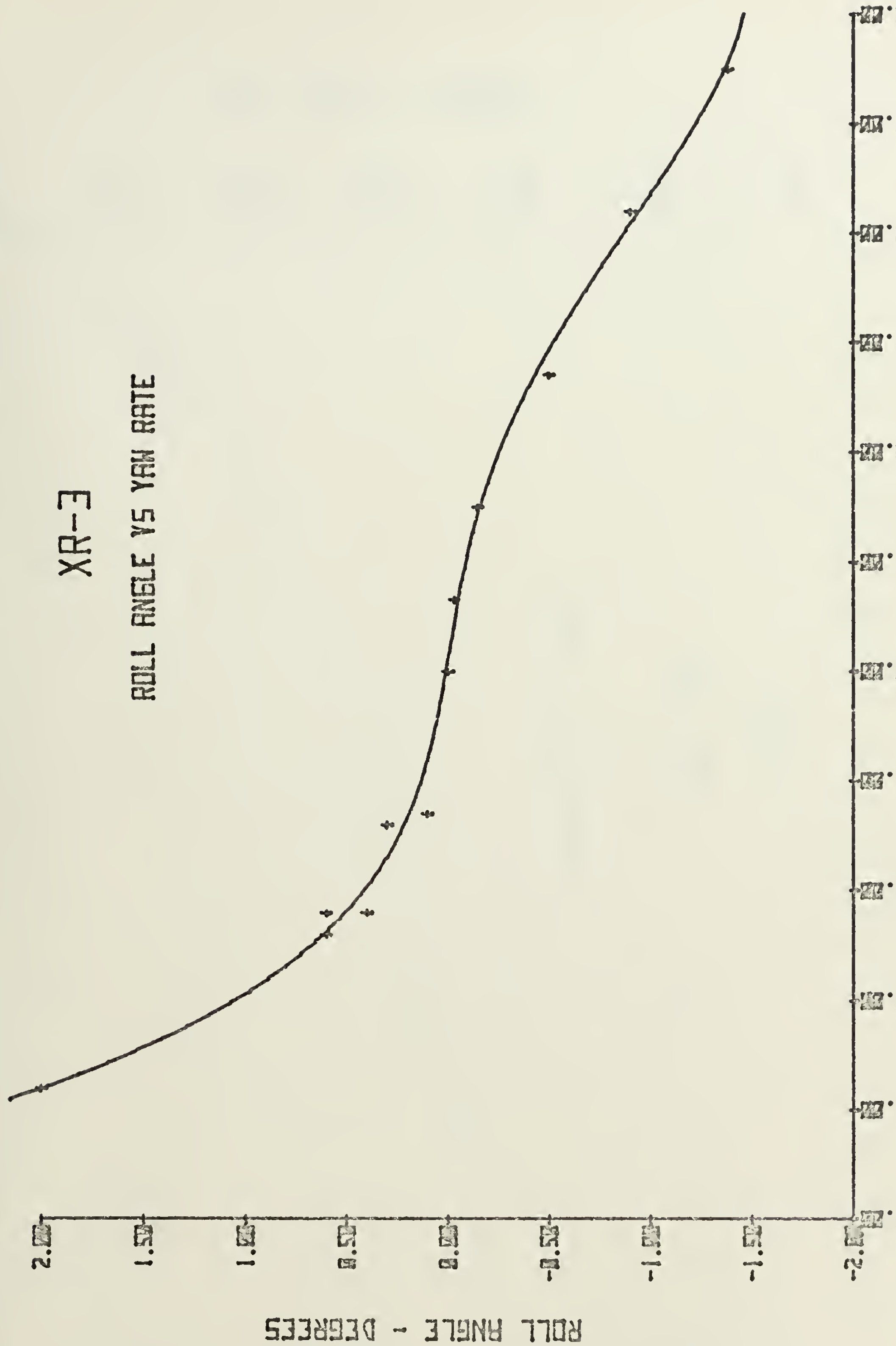
XR-3
ROLL ANGLE VS YAW RATE
YAW RATE - DEGREES PER SECOND
ROLL ANGLE - DEGREES

FIGURE 13


ROLL ANGLE - DEGREES
-1.50
-1.00
-0.50
0.00
0.50
1.00
1.50
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
X10-2
XR-3
ROLL ANGLE
VS
LATERAL ACCELERATION

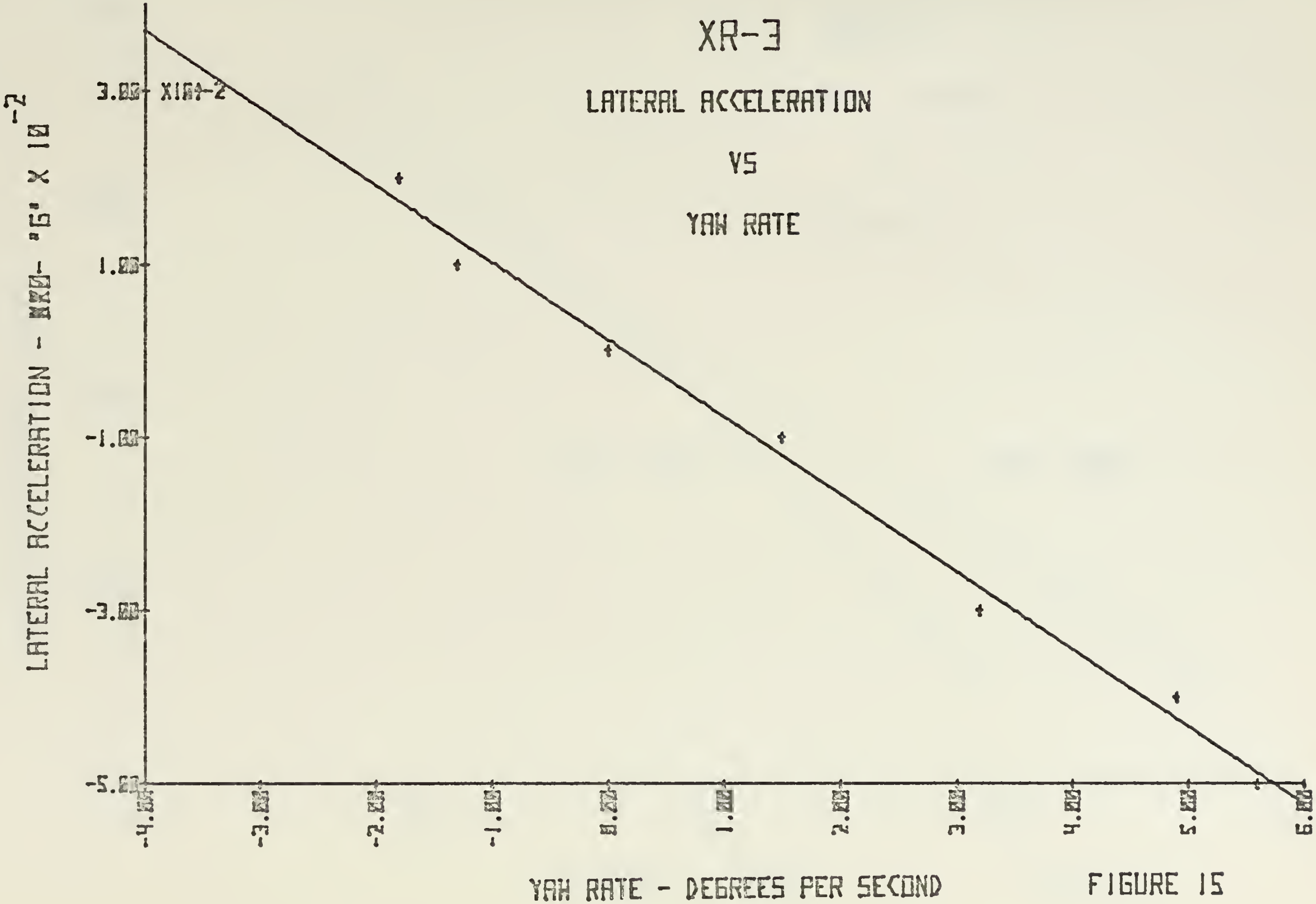
XR-3
LATERAL ACCELERATION
VS
YAW RATE
LATERAL ACCELERATION - ▒▒▒- "G" X 10^{-2}
3.00 X10^{-2}
1.00
-1.00
-3.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
YAW RATE - DEGREES PER SECOND

FIGURE 15

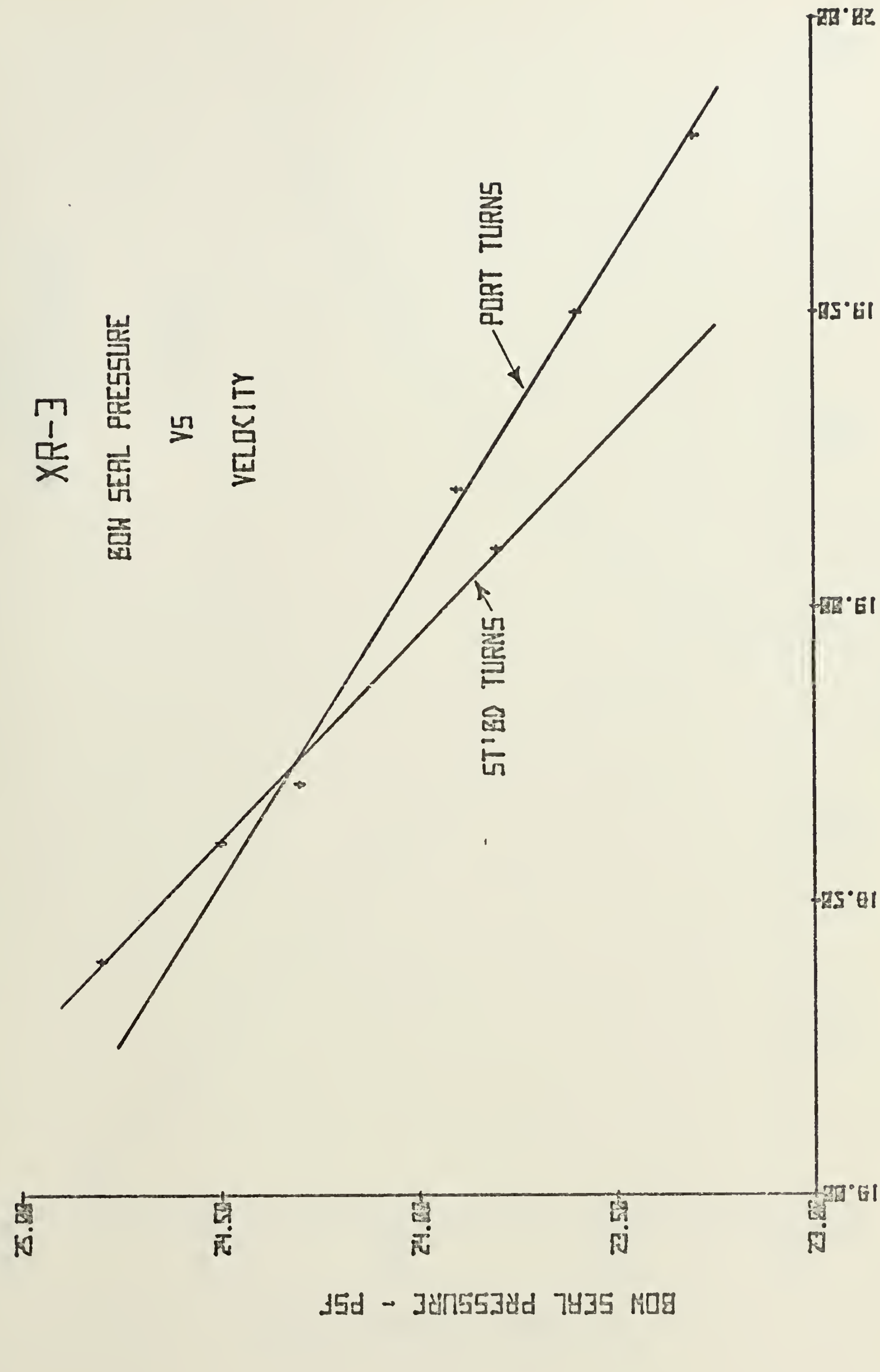
XR-3
BOW SEAL PRESSURE
VS
VELOCITY
PORT TURNS
ST'BD TURNS
VELOCITY - KNOTS
BOW SEAL PRESSURE - PSF
18.00
18.50
19.00
19.50
20.00
23.00
23.50
24.00
24.50
25.00

FIGURE 16

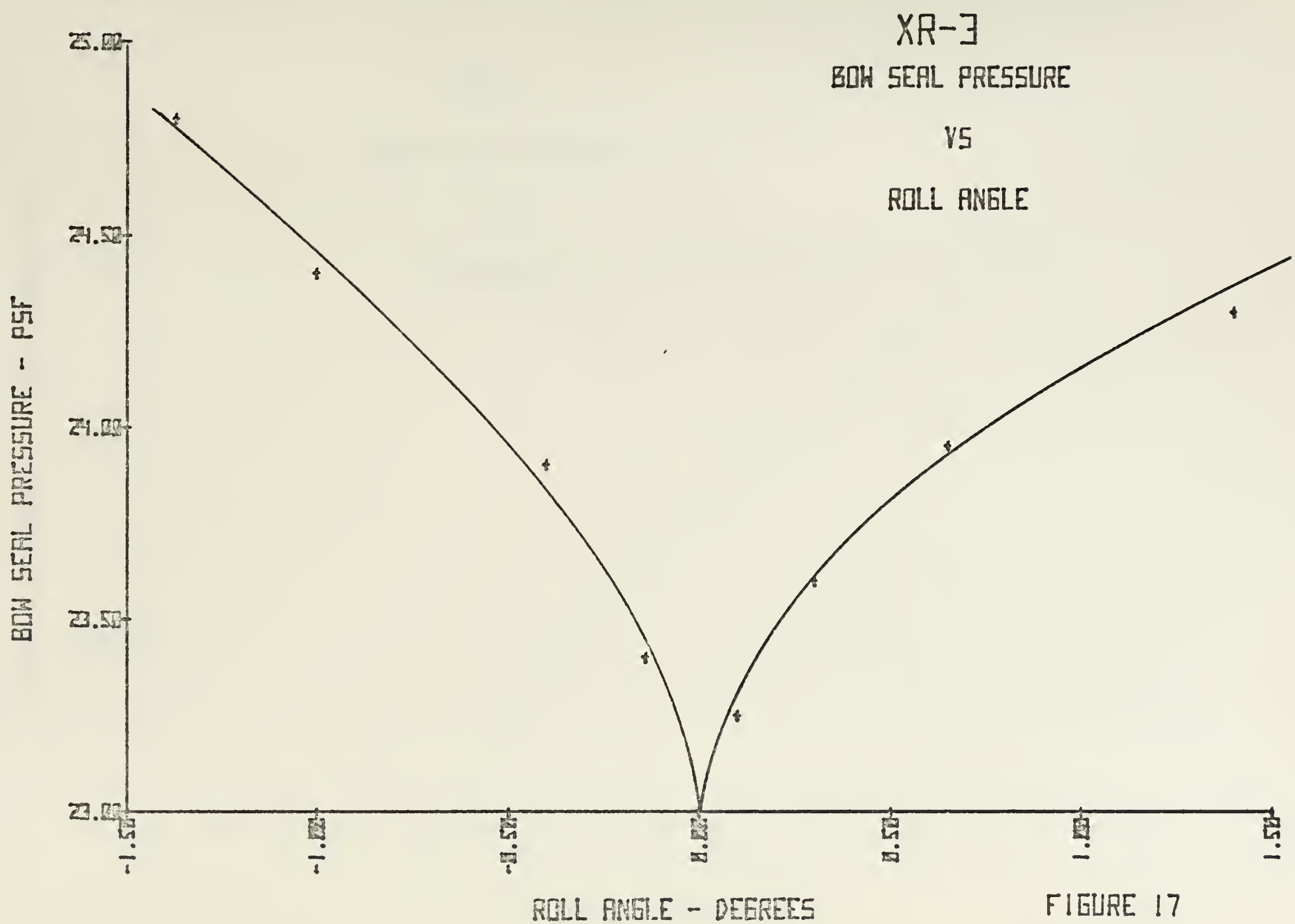
XR-3
BOW SEAL PRESSURE
VS
ROLL ANGLE
25.00
24.50
24.00
23.50
23.00
BOW SEAL PRESSURE - PSF
-1.50
-1.00
-0.50
0.00
0.50
1.00
1.50
ROLL ANGLE - DEGREES

FIGURE 17

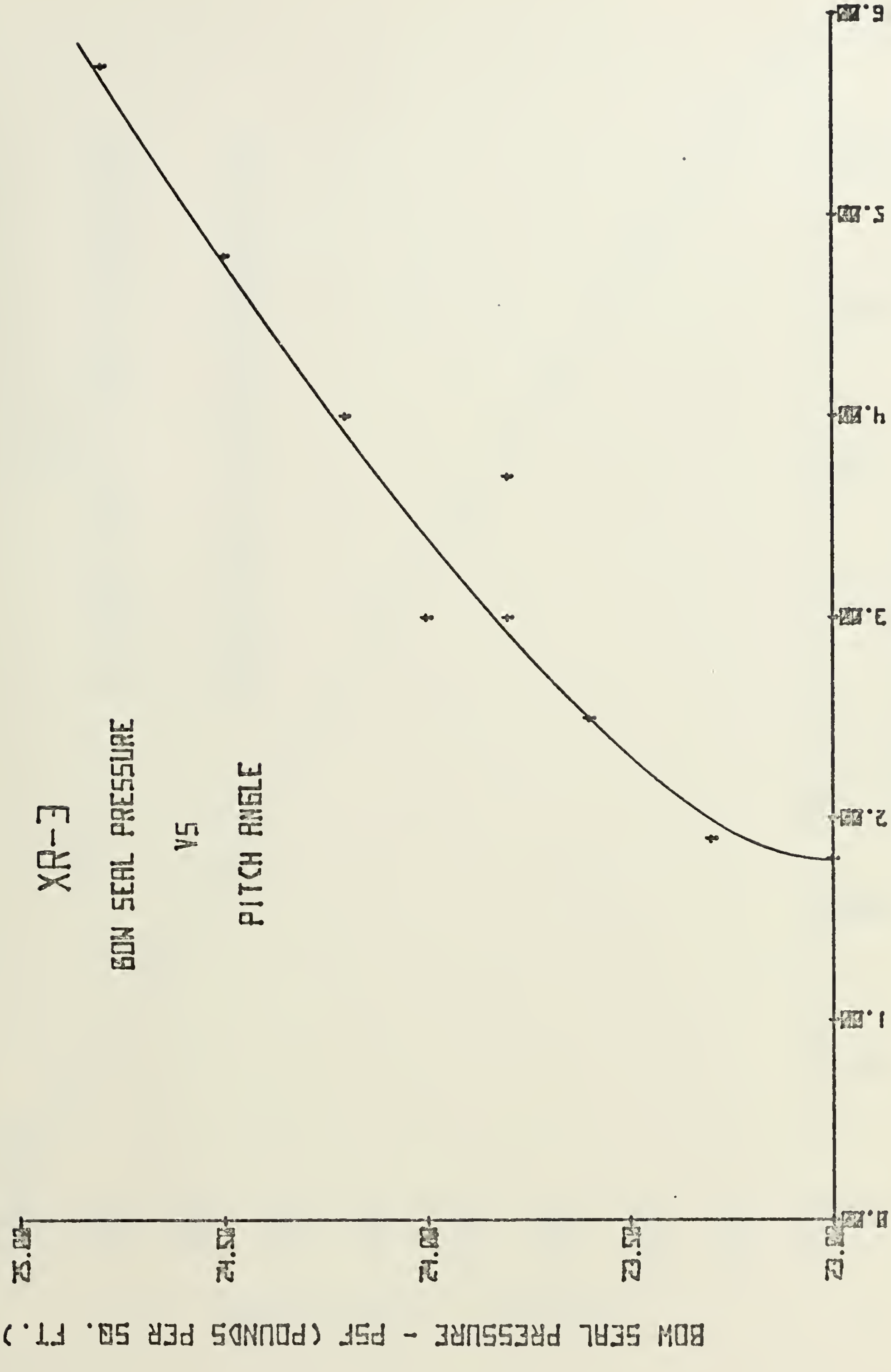
XR-3
BOW SEAL PRESSURE
VS
PITCH ANGLE
PITCH ANGLE - DEGREES
BOW SEAL PRESSURE - PSF (POUNDS PER SQ. FT.)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
23.00
23.50
24.00
24.50
25.00

FIGURE 18

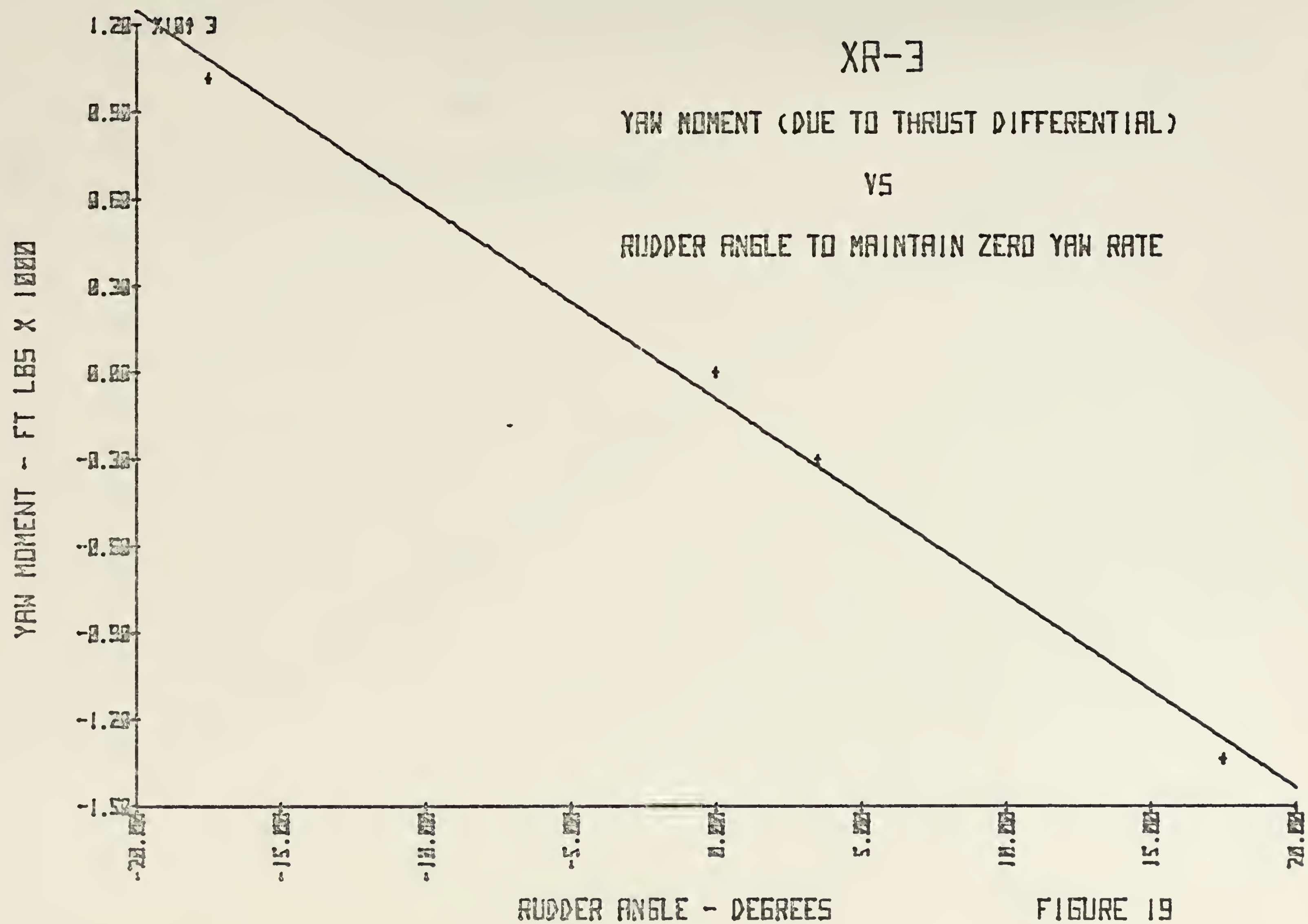
XR-3
YAW MOMENT (DUE TO THRUST DIFFERENTIAL)
VS
RUDDER ANGLE TO MAINTAIN ZERO YAW RATE
X10↑ 3
1.20
0.90
0.60
0.30
0.00
-0.30
-0.60
-0.90
-1.20
-1.50
YAW MOMENT - FT LBS X 1000
-20.00
-15.00
-10.00
-5.00
0.00
5.00
10.00
15.00
20.00
RUDDER ANGLE - DEGREES

FIGURE 19

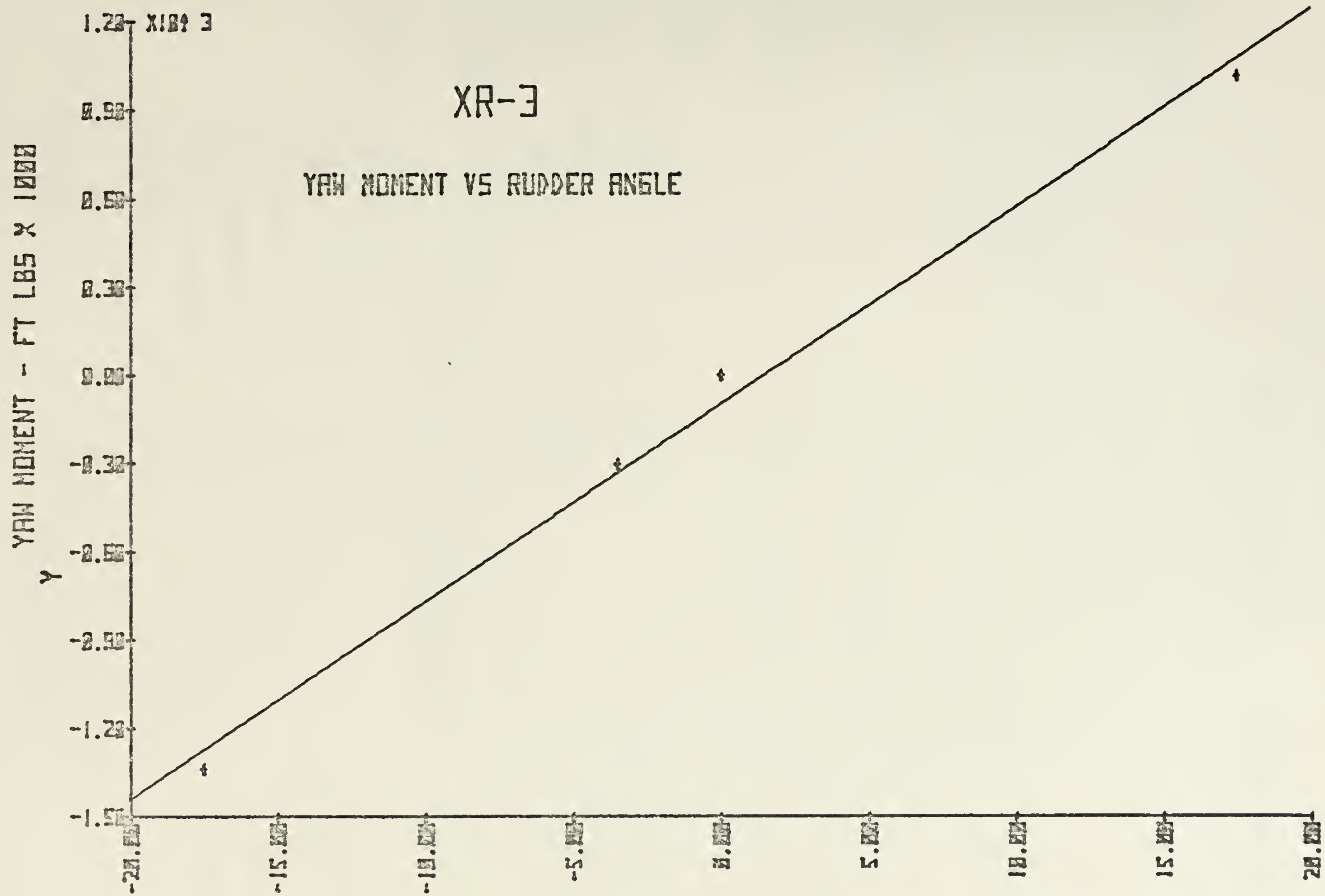
XR-3
YAW MOMENT VS RUDDER ANGLE
YAW MOMENT - FT LBS X 1000
Y
RUDDER ANGLE - DEGREES

FIGURE 19A

APPENDIX A

TRANSDUCER LOCATION

		Distance Forward of Transom	Distance from Center Line
PRESSURE			
	Bow Seal	18' 4"	
*	Plenum (Forward)	16'	
*	Plenum (Aft)	12' 4½"	
	Stern Seal	1' 6"	
VELOCITY		21' 9"	
		4' 9½" down from Deck	
HEIGHT		24' 1"	
		6" down from Deck	
GYRO			
	Pitch	12' 6"	2' 4½" Port
	Roll	13'	2' 4½" Port
	Yaw	12' 6"	2' 4½" Port

* Either of these pickups can be monitored by one transducer

SIGNIFICANT MEASUREMENTS

Center of Gravity			
	Pilot	15' 9"	2' 2" Starboard
	Co-Pilot	15' 9"	2' 2" Port
	Fuel (Outboard)	10' 3"	2' 2" Port
	Fuel (Outboard)	10' 3"	2' 2" Starboard
	Fuel (Lift	10' 3"	2' 2" Port
Plenum Dimensions			
	Length	17' 8" (Rear of Bow Seal to Rear of Stren Seal)	
	Width	10'	
	Height	1' 10"	

APPENDIX B

RANGE OF MEASUREABLE PARAMETERS

Parameter	Range	
Thrust (Port)	0 - 500 lbs	$\pm$ 5 lb
Thrust (Starboard)	0 - 500 lbs	$\pm$ 5 lb
Velocity	0 - 40 knots	$\pm$ 1 kt
Pressures	0 - 60 psf	$\pm$ 0.5 psf
Pitch Angle	$\pm 15^\circ$	$\pm 0.5^\circ$
Roll Angle	$\pm 15^\circ$	$\pm 0.5^\circ$
*Pitch Rate	$\pm 30^\circ$/sec	$\pm 0.5^\circ$/sec
Roll Rate	$\pm 30^\circ$/sec	$\pm 0.5^\circ$/sec
Yaw Rate	$\pm 30^\circ$/sec	$\pm 0.5^\circ$/sec
Rudder Position	$\pm 45^\circ$	$\pm 1^\circ$
Acceleration (Surge and Sway)	$\pm$ 0.2 g	
Acceleration (Heave)	- 0.8 to + 1.2g	

LIST OF REFERENCES

1. Naval Ship Research and Development Center ltr PM1731A, XR-3 Testing, 20 August, 1973.

2. Naval Ship Research and Development Center Memo, Code 1576, XR-3 Testing, 14 February, 1974.

3. Naval Ship Research and Development Center Memo (undated) as amplified by discussions between Mr. Wilson of NSRDC and Professor D. M. Layton of NPS on 20 February, 1974.

4. Naval Postgraduate School, XR-3/74-1, Simulation Model Validation Test Plan XR-3, 4 March 1974.

5. Naval Postgraduate School, XR-3/74-0, General Test Plan XR-3, 4 March, 1974.

6. Feeney, James L., XR-3 Data Acquisition System for Performance Evaluation, M.S. Thesis, Naval Postgraduate School, March, 1973.

7. O'Malley, John Francis and Belden, William E., Design Modification and Preliminary Performance Evaluation of the XR-3, A Captive Air Bubble Testcraft, M.S. Thesis, Naval Postgraduate School, June, 1973.

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